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A new North American Endophyllum*

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(WITH PLATE 2 AND TWO TEXT FIGURES)

The genus *Endophyllum*, of which *E. Sempervivi* is the type and the best known example, is distinctive in that its spores, to all outward appearances aeciospores, being accompanied by intercalary cells and a peridium and borne in an Aecidium-like fructification, are in reality true teliospores that give rise to promycelia and basidiospores on germination, as Hoffman† and others have conclusively demonstrated. *Gymnoconia*, thought to be an aecial form until the recent notable work of Kunkel‡ on *G. interstitialis*, is to be considered an allied genus, in which the teliospores have intercalary cells but are not enclosed in a peridium. In both cases the vegetative mycelium is perennial in the tissues of the hosts and the life histories are completed with the production of a single spore form, the teliospore, in addition to the basidiospores and pycniospores.

During the past summer we have succeeded in demonstrating the *Endophyllum* character of *Aecidium tuberculatum* Ellis & Kellerm., a rust of the western prairies and uplands on malvaceous plants, especially *Callirhoë involucrata*.

The *Callirhoë* rust has been an object of investigation by the

* Read before the Botanical Society of America at the Philadelphia meeting, December 29, 1914.

† Hoffman, A. W. H. Centralbl. f. Bakt. 2 Abt. 32: 137–158. 1912.

‡ Kunkel, L. O. Bull. Torrey Club 40: 351–366. *pl. 3*. 1913. Am. Jour. Bot. 1: 37–47. 1914.

[The BULLETIN for January (42: 1–54, *pl. 1*) was issued January 29, 1915.]

botanical department of the Purdue Experiment Station for the past ten years and during a considerable part of this period infected plants of *Callirhoë involucrata* have been grown in the experimental garden at Lafayette. The probable *Endophyllum* character of the form was recognized at the first from certain features in the structure of the sorus, the perennial mycelium, and the failure of field studies to disclose any likely alternate stage. In order to test this assumption it was necessary to have material near at hand for germination and infection studies and Mr. E. Bartholomew of Stockton, Kansas, very kindly sent infected *Callirhoë* plants for this purpose. The first consignment of these plants was received in 1904 and they were subsequently grown in the garden three or four years, producing aecia each year. Germination tests of the spores made by the senior writer in 1907 disclosed only non-septate germ tubes (TEXT FIG. 1) and the conclusion was reached

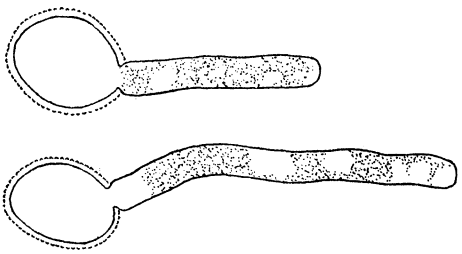


FIG. 1. Teliospores of *Aecidium tuberculatum* germinated in a Van Tieghem cell. After a drawing by F. D. Kern in 1907.

that the spores were true aeciospores and the structure an aecium in spite of the inferential evidence to the contrary. We now know that the method of germination commonly employed in such tests, the hanging drop of the Van Tieghem cell, was responsible for the failure to discover the true character of the germination.

Early in the present year of 1914 Mr. Bartholomew sent another shipment of infected plants of *Callirhoë involucrata* and germination tests were again instituted. The method of germination employed by Kunkel, sowing on the surface of a non-nutrient agar, was used with complete success. Promycelia and basidiospores were produced in abundance in the first test and in the score or more of subsequent tests that were made, proving conclusively that the spores are in reality teliospores.

With these results in mind a search was made for other aecia on malvaceous hosts that might be of a similar nature. An unnamed species of *Aecidium* on *Sidalcea* and *Althaea*, hitherto considered distinct from *Aecidium tuberculatum*, proved to be so similar morphologically that the identity of the two seemed most probable. The *Sidalcea* form had been tentatively connected with a grass rust, *Puccinia Deschampsiae*, from field studies in Colorado by Mr. E. Bethel, that were afterward inspected by Dr. F. D. Kern and the senior writer in company with Mr. Bethel. Mr. Bethel's field attempts to prove this connection, made at Eldora and Denver, Colorado, and reported to us, had, however, been unsuccessful. At our request, Mr. Bethel sent us, last September, plants of *Sidalcea candida* infected with the *Aecidium* in question. These spores on germination likewise produced promycelia and basidiospores (FIG. 7) identical with those of *Aecidium tuberculatum*. The identity of the two forms, therefore, seems certain.

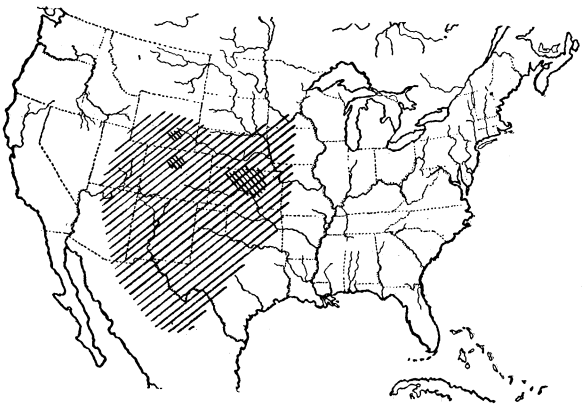


FIG. 2. Distribution of *Aecidium tuberculatum* and its hosts. Diagonal lines indicate approximate distributions of *Callirhoë involucrata*, *Sidalcea candida*, and *S. neo-mexicana;* cross hatching shows areas covering known distribution of *Aecidium tuberculatum*.

The form is known on *Althaea rosea* from the single locality of Red Cloud, Nebraska, where it was collected by the Rev. J. M. Bates in 1910 and where the *Callirhoë* rust is reported as "everywhere." Although we have had no opportunity of testing the germination of its spores there is no real question of its identity with the *Callirhoë* and *Sidalcea* rust.

The type of *Aecidium tuberculatum* was collected by Mr. E. Bartholomew on leaves of *Callirhoë involucrata*, Rooks County, Kansas, September 15, 1887. It has since been found on this host at several stations on the prairies of eastern, central and western Kansas and southern Nebraska. The *Sidalcea* rust is known from several points in the mountains of central Colorado and from a single collection in south central Wyoming (TEXT FIG. 2).

The infection of the various hosts through the sowing of basidiospores has not so far been demonstrated but experiments are under way the results of which should be apparent next spring.

Pycnia are apparently obsolete in this species; a careful search of infected leaves and a study of microtome sections brought forth no traces of them.

The teliospores are normally one-celled, but occasional two-celled spores are produced and one or more of them may be found in any mount (FIG. 2). Their wall thickness, coloring and verrucose sculpturing is like that of the one-celled spores, from which they differ only in form and the presence of a horizontal median septum. They are found in microtome sections of the sori scattered among the one-celled spores in the upper part of the spore chains. Each cell contains two nuclei the products of the conjugate division of the two nuclei of the one-celled spores from which they arise by a vegetative development.

These two-celled teliospores of *Aecidium tuberculatum* are suggestive of those found normally in the genus *Pucciniosira*, which has catenulate, uniseptate teliospores accompanied by a peridium and borne in a cupulate telium that is to all external appearances a true, but diminutive, aecidium. The other morphological features of the sorus and spores of *Aec. tuberculatum*, especially the large, bullate sorus, the fragile, slightly differentiated peridium, and the breaking apart of the spore chains in older sori giving the impression that the spores are compacted without order are, however, characteristic of the genus *Endophyllum* to which it is, therefore, now referred.

Endophyllum tuberculatum (Ellis & Kellerm.) comb. nov.

Aecidium tuberculatum Ellis & Kellerm. Jour. Myc. **4**: 26. 1888.

O. Pycnia unknown, probably not formed.

III. Telia aecidioid, hypophyllous and caulicolous, diffused, from a perennial mycelium, following the veins or covering large areas, round or elliptical, bullate, large, 0.5–1 mm. broad by 0.5–1.5 mm. long, yellowish or orange when fresh; peridium colorless, opening at first by a small apical pore, soon disappearing; peridial cells oblong, slightly larger than the teliospores, the outer wall smooth, transversely striate, 5–7 μ thick, the inner coarsely verrucose, thinner, 1–3 μ; teliospores angularly globoid or oblong, occasionally with a transverse, median septum, 16–26 by 18–30 μ; wall pale yellow, moderately thin, 1–2 μ, closely and rather prominently verrucose.

On *Althaea rosea* L.: Nebraska (Red Cloud, October 6, 1910, *Bates*).

On *Callirhoë involucrata* (T. & G.) A. Gray: Kansas (Rockport, now called Stockton, May 20, 1889 in Kellerm. & Swingle, Kan. Fungi *30*, May *22*, 1894, Stockton, May 25, 1911 in Barth. N. Am. Ured. *302*, Rooks County, September 15, 1887, May 25, 1897 in Sydow, Ured. *1199*, June 2, 1902, Manhattan, May 1893 in Carleton, Ured. Am. *31*, all by *Bartholomew;* Osborne County, June 1891, *Brown;* Osborne, May 1894 in Rab.-Wint.-Paz. Fungi Eur. 4239, *Shear;* Decatur County, June 1892, *Hitchcock;* Wichita, June 7, 1893, *Carleton*); Nebraska (Red Cloud, May 2, 1903, May 9, 1903, May 14, 1911 in Barth. N. Am. Ured. *601*, *Bates*).

On *Sidalcea candida* A. Gray: Colorado (Eldorado Springs, August 19, 1909, Eldora, September, 1910, Lake Eldora, August 7, 1910, September 17, 1910, August 25, 1911, Tolland, October 29, 1910, September 20, 1914, all by *Bethel*; Routt County, July 16, 1894, *Crandall*).

On *Sidalcea neo-mexicana* A. Gray (*S. malvaeflora* Coulter in Bot. Rocky Mt. Region, not A. Gray): Colorado (Sulphur Springs, November 1910, August 14, 1910, *Bethel*); Wyoming (Seminole Mts., Carbon County, July 23, 1898, *E. & A. Nelson*).

Type collected in Rooks County, Kansas, on leaves of *Callirhoë involucrata*, *E. Bartholomew 25* (September 15, 1887).

DISTRIBUTION: from eastern Kansas and southern Nebraska to north central Colorado and southern Wyoming.

The germination stages of the teliospores of *End. tuberculatum* are similar to those described by Kunkel for *Gym. interstitialis* and by Hoffman for *End. Sempervivi*. The promycelium is formed at one end of the ellipsoid spore and usually attains its full length,

about 90 μ, before the septa appear. The promycelium is divided, as a rule, into four uninucleate basidiospore initial cells and a basal stalk (FIGS. 6–12). Each basidiospore initial cell gives rise to an ellipsoid basidiospore on a sterigma (FIGS. 7–9). Under suitable conditions the basidiospore germinates at maturity with a slender germ tube that may issue from the apex (FIGS. 6, 8) or from the base near the attachment of the sterigma (FIG. 9).

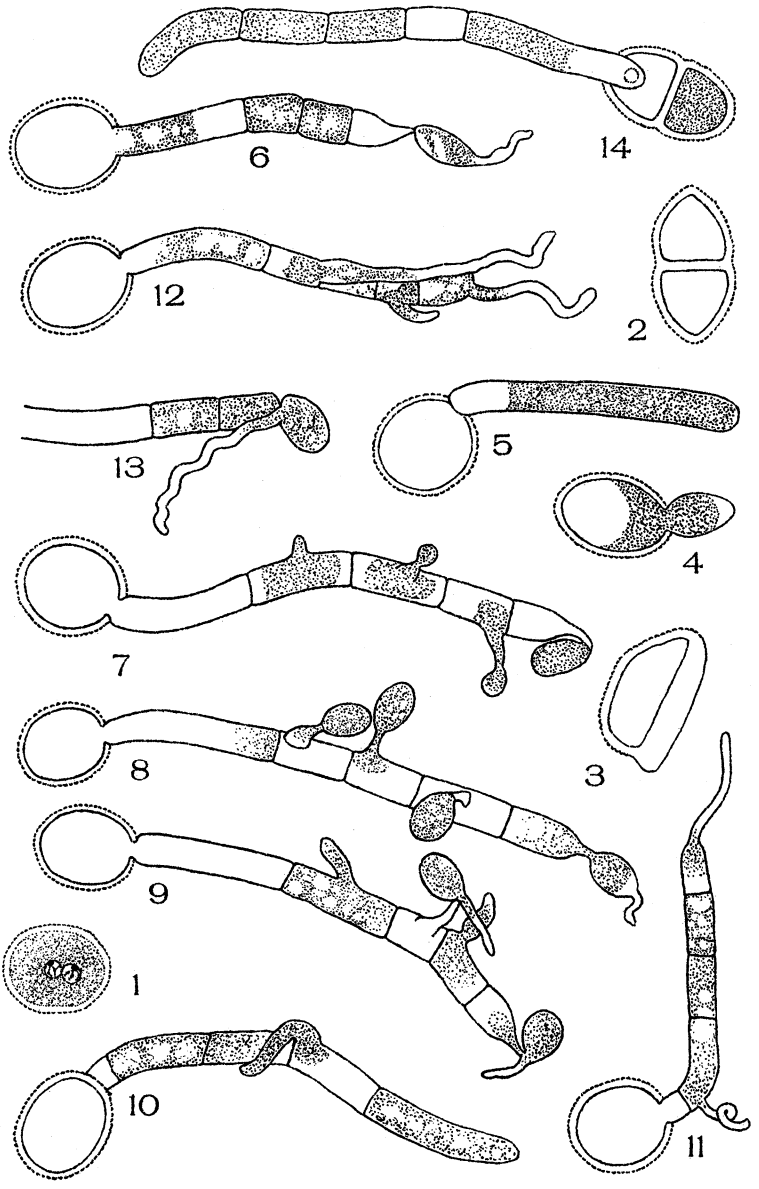
The common practice of germinating rust spores in the inverted drop of the Van Tieghem cell is undoubtedly the reason why the true character of the very common and much studied *Gym. interstitialis* remained obscure for so many years and Kunkel's discovery is attributable to the important departure in method of germination that he employed.

The production of basidiospores is dependent to a considerable degree on the exposure of the promycelium to a free air surface. If the teliospores are floated on an upright drop of tap water on a slide placed in a damp chamber basidiospores are freely formed, but if sown in an inverted drop of water in a Van Tieghem cell no basidiospores are produced and spore germination may be totally inhibited. A drop of a five percent non-nutrient gelatin may be substituted for the upright drop of water to secure greater stability. If spores are available in large quantities they may be dusted on the surface of water or non-nutrient gelatin or agar in a petri-dish. On a moderately hard agar the basidisopore initial cells produce germ tubes directly without the formation of basidiospores (FIGS. 10–13).

That the moisture and air relations under which teliospores are germinated have a marked effect on the character of their germination has also been shown by Klebahn,* who worked with teliospores of *Puccinia malvacearum*. He found that normal promycelia and basidiospores were produced if the spores were in contact with air and not surrounded by a film of water, but if surrounded by water with the air shut out only long thin tubes were formed.

There is perhaps no basis on which species with aecidioid telia can be distinguished from the aecia of long-cycle forms except in the behavior of their spores on germination. A perennial

* Klebahn, H. Zeitsch. f. Pfl. kr. **24**: 1–32. 1914.



ENDOPHYLLUM TUBERCULATUM (ELLIS & KELLERM.) ARTHUR & FROMME

mycelium is no doubt a constant corollary and necessity for all such short-cycle rusts that depend on a non-resting teliospore for propagation in temperate or arctic regions. It is probable that other species, now placed in the form genus *Aecidium* and considered unconnected aecial stages of heteroecious rusts, will prove to be short-cycle forms like *Endophyllum tuberculatum*. Suitable germination tests of such species will decide the matter.

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Explanation of plate 1

ENDOPHYLLUM TUBERCULATUM (Ellis & Kellerm.) Arthur & Fromme

All figures drawn with the camera lucida at an approximate magnification of 625 diameters. FIG. 7 is from *Sidalcea candida*, all others from *Callirhoë involucrata*.

FIG. 1. A one-celled spore showing two nuclei.

FIG. 2. A two-celled spore.

FIG. 3. A peridial cell.

FIGS. 4, 5. Early germination stages of one-celled spores.

FIGS. 6–9. Later germination stages with septate promycelia producing basidiospores.

FIGS. 10–13. Promycelia the cells of which have produced germ tubes.

FIG. 14. A germinating two-celled spore; one of the cells has produced a promycelium.